

2011 DOE-OE Peer Review,
Oct. 20~21, 2011, San Diego

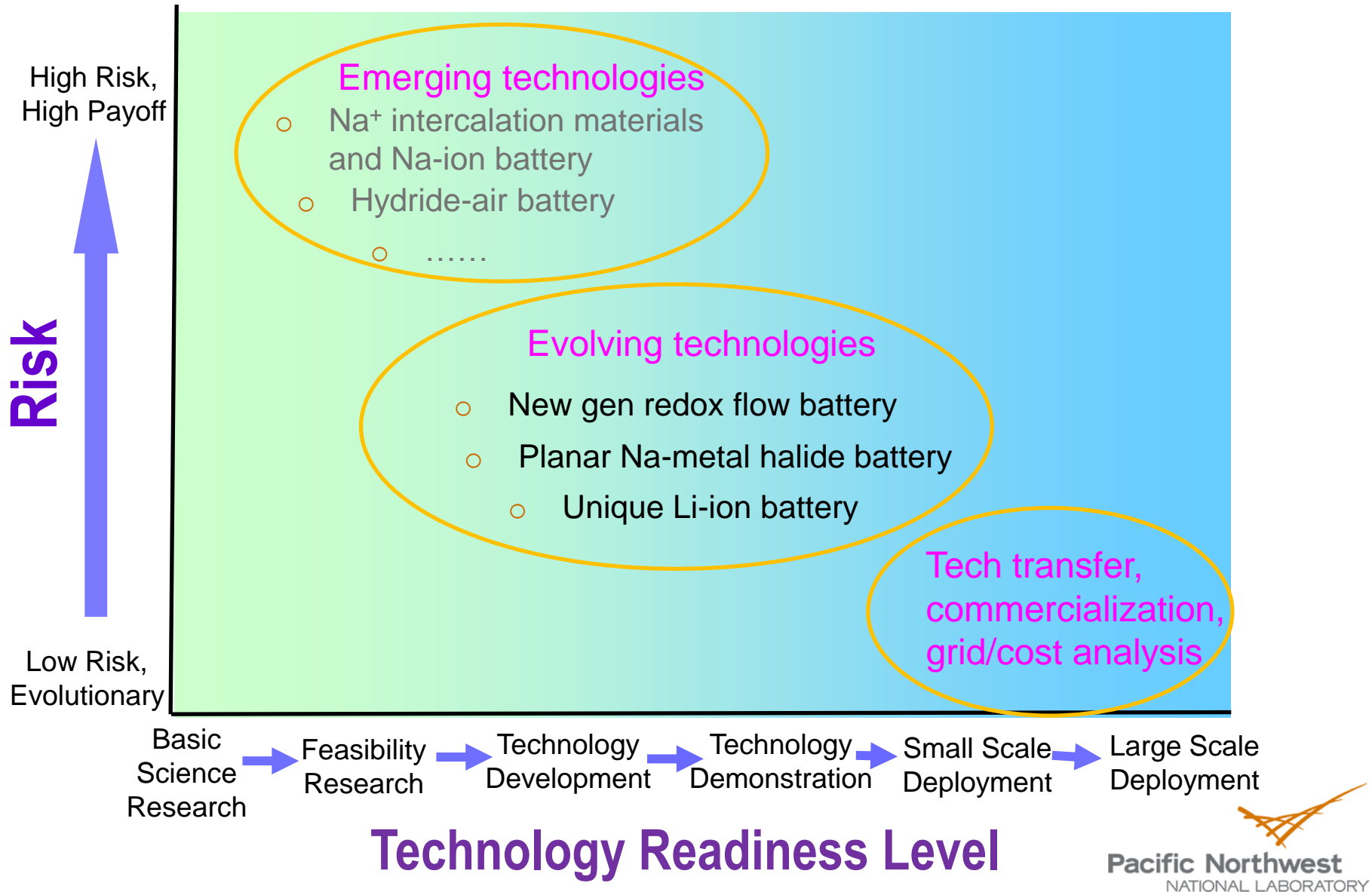
Electrical Energy Storage RD&D at PNNL

Z. Gary Yang

Special thanks to:

Dr. Imre Gyuk, Manager of DOE-OE Storage Program

Electrical energy storage (EES) RD&D at PNNL

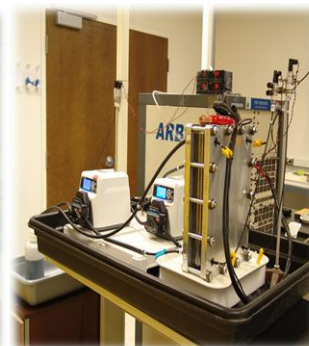
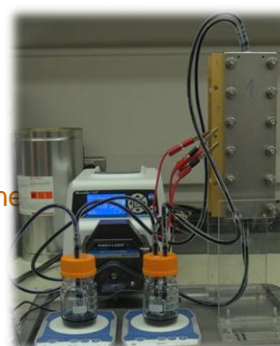
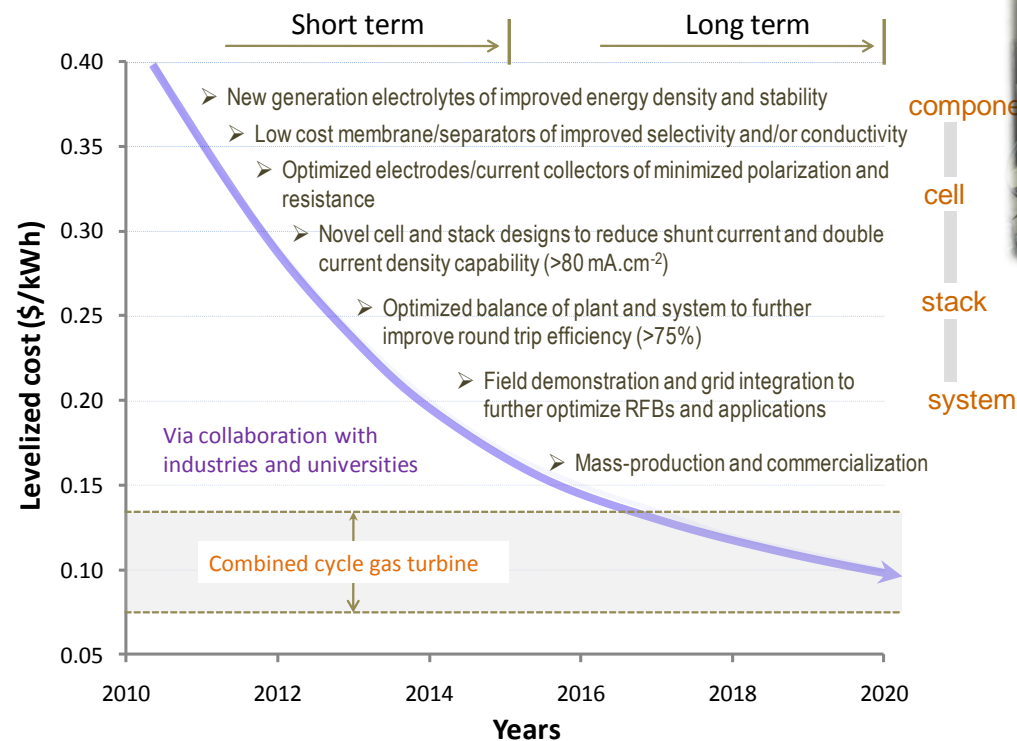
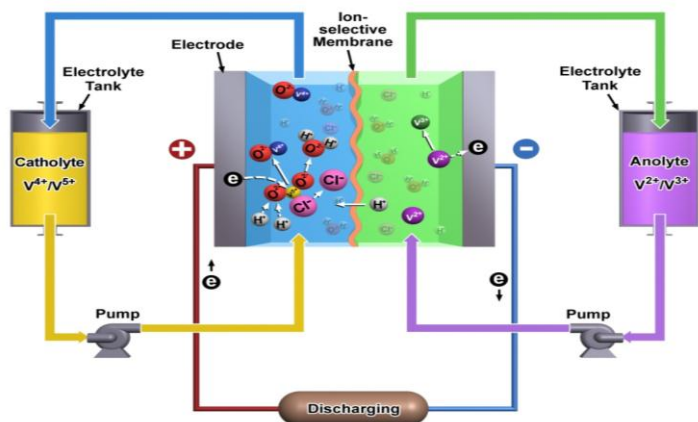


Redox flow battery (RFB)

(Dr. Liyu Li will report details)

Develop new generation redox flow batteries (RFBs) to improve performance and economics and accelerate commercialization, via collaboration with:

- SNL, Penn State and ONL/UT on alternative membranes
- DuPont, Daramic, GraphTech, SGL, ..., on components
- Battery industries via technology transfer and co-development



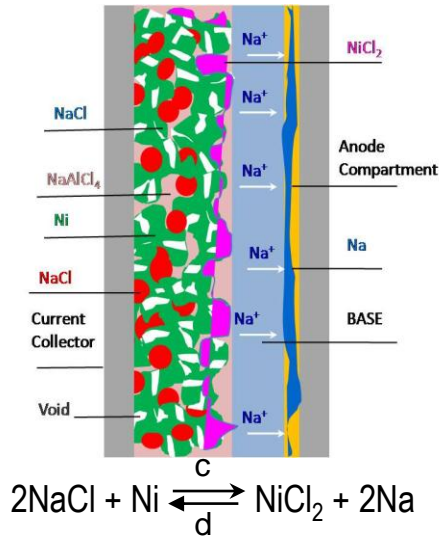
- Developed 3rd gen all vanadium RFB
- Discovered Fe/V redox couples
- Optimizing cell/stack components and designs
- Demonstrate bench-top systems

Na-metal halide batteries (NMB)

(Dr. Vince Sprenkle will report details)

Develop planar Na-metal halide batteries that can meet cost and performance targets for renewable integration and grid applications, via introduction of new designs and new electrode chemistries and interfaces

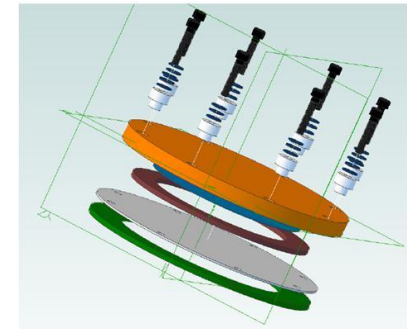
- Collaborate with EaglePicher Technologies, LLC
- Leveraging ARPA-E support



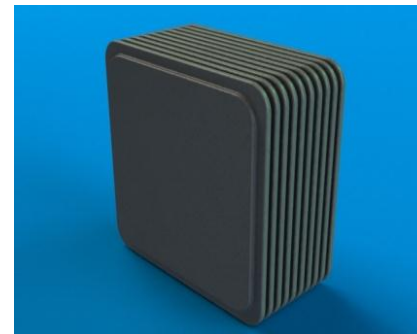
3.0cm² Button Cell



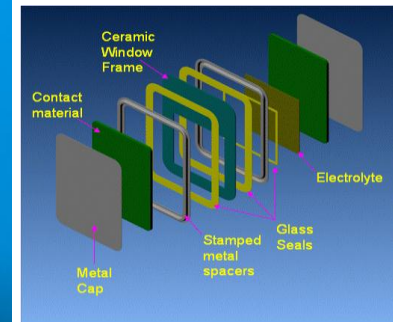
64cm² XL-Button Cell



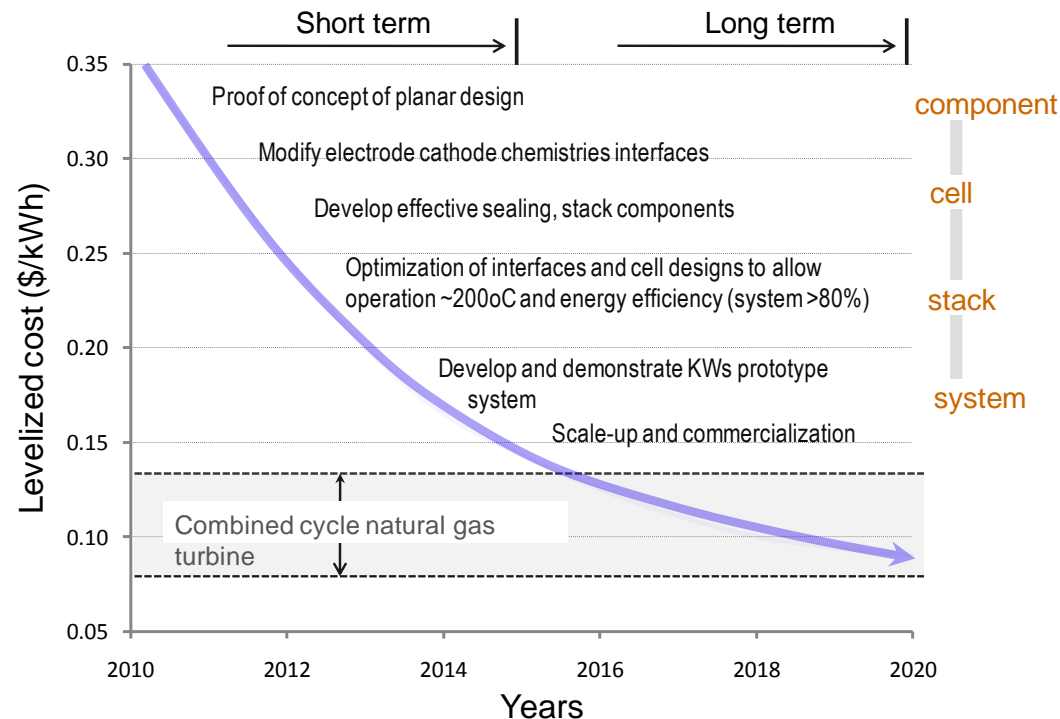
200cm² Stack



100cm² Planar Cell



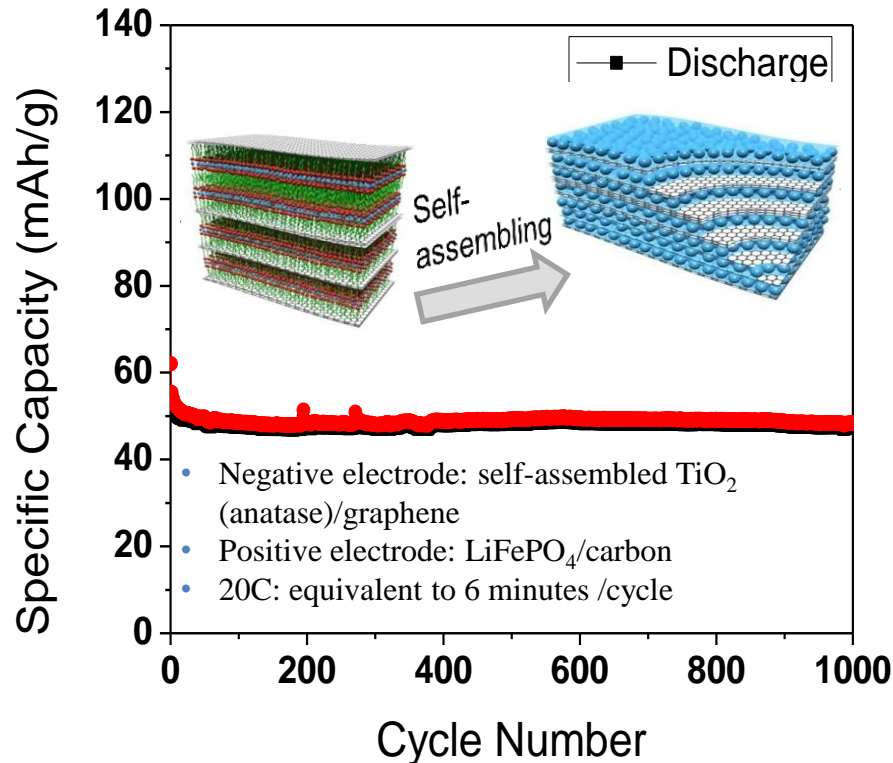
- Proved concept of the planar design
- Scaled up to intermediate size
- Met major performance targets
- Develop and demonstrate 5kW prototype system in 2012



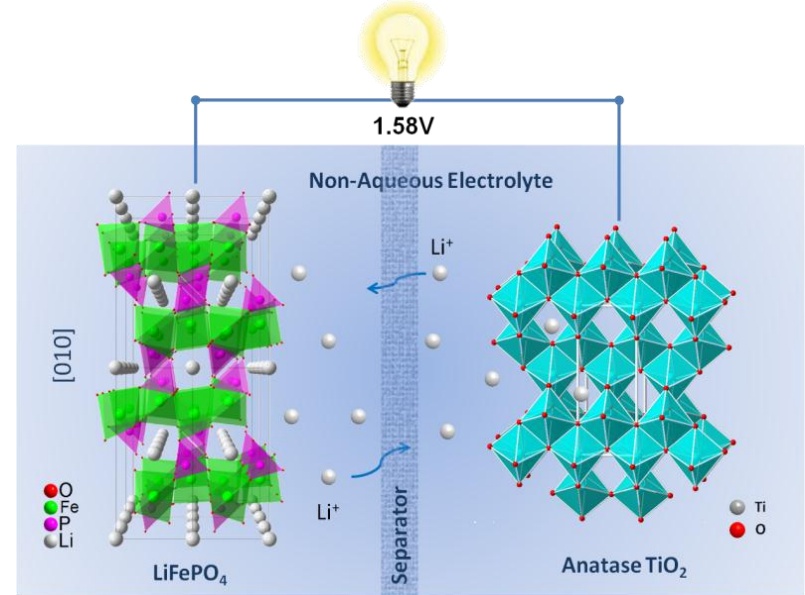
Unique Li-ion for community storage

Develop unique Li-ion batteries that are made from low cost (<\$250/kWh), high cycle life (>5,000 deep cycles) electrode materials to meet, in particular, the cost and performance requirements for community storage

- Collaborate with K2 Energy, Penn State



Dr. Daiwon Choi reports details in his poster



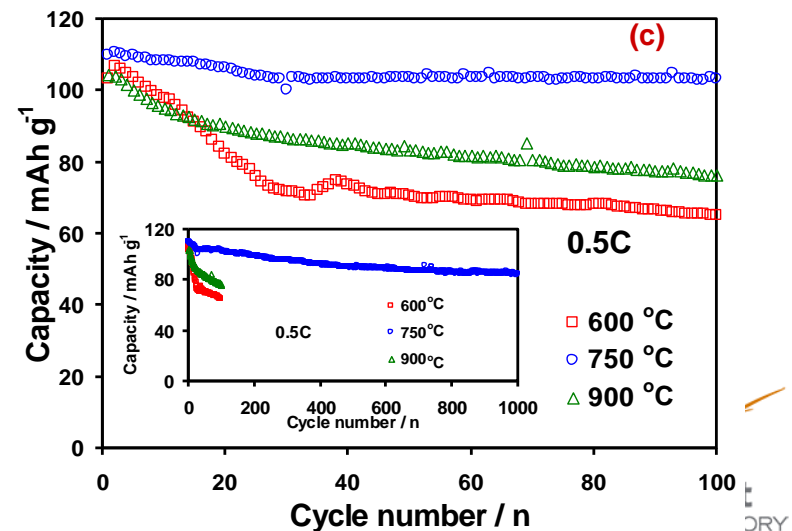
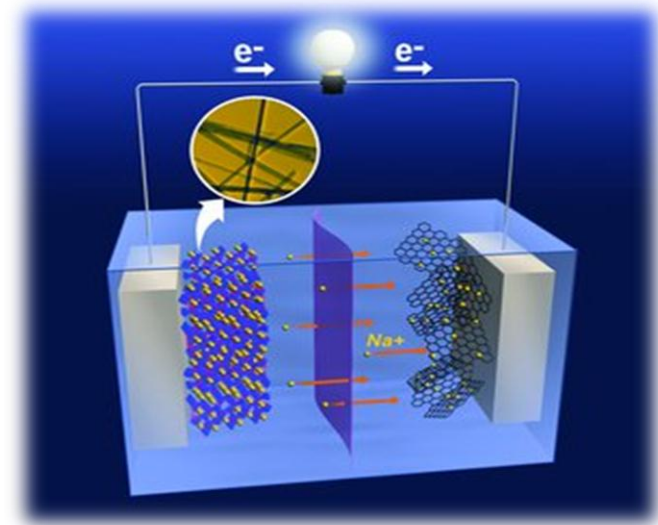
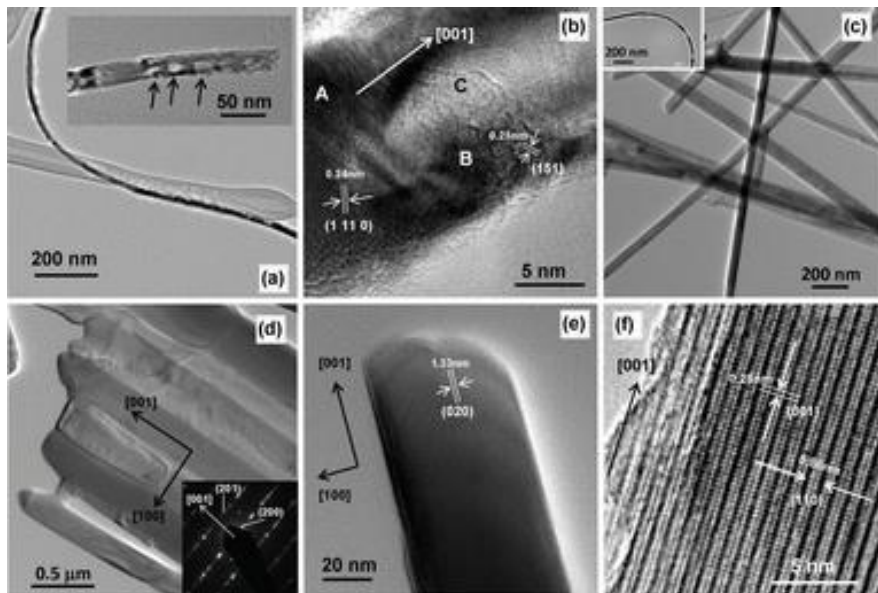
- Self-assembled nanostructured TiO₂(anatase)-base anode; LiFe(Mn)PO₄ cathode
- Achieved >2,000 full cycles (100% DOD)
- Develop and optimize practical size batteries in FY12

Emerging EES technologies: Na-ion battery

Dr. Jun Liu (Dr. Yuyan Shao) report details

Develop new concepts/technologies that can lead to transformational improvement in performance and economics

- Synthesized single crystalline $\text{Na}_4\text{Mn}_9\text{O}_{18}$ nanowires via polymer pyrolysis, as cathodes
- Proved facile Na^+ intercalation/deintercalation
- Achieved stable 1,000 cycles at 0.5C, with <0.1% capacity fade per cycle
- Developing novel carbon structure as anodes
- Demonstrate Na^+ -ion cells for stationary applications



Analytics on EES for grid applications

*Dr. Michael Kintner-Meyer will present details;
Dr. Vish Viswanathan reports cost analysis in his poster*

300 GW Wind

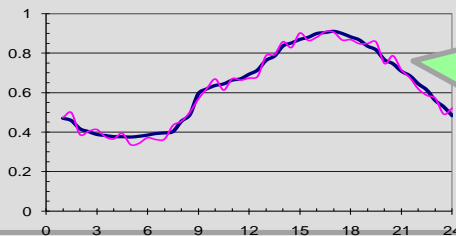


Meeting Balance
Requirements

Actual
production

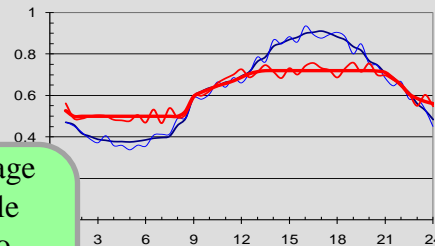
Generation
schedule

Real-time operation



Energy storage
is an valuable
grid assets to
provide
balance
services

Arbitrage



Infrastructure
deferment

when

- Located at strategic location in bulk power to reduced congestion
- In distribution system/home to reduce distribution congestion

Reliability value

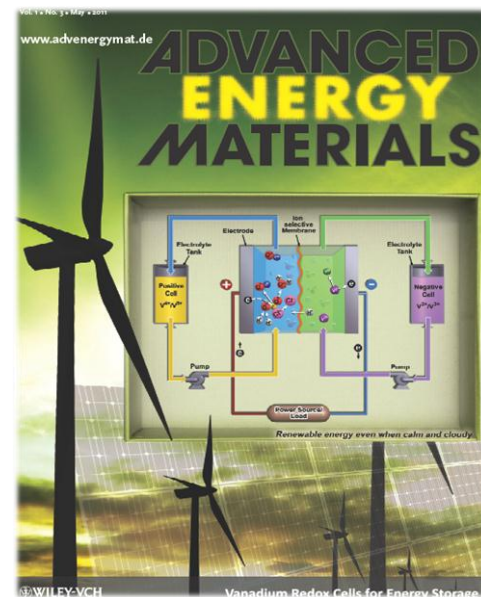
Economic value



PNNL Electric Infrastructure Operations

Accomplishments in FY11

- ▶ 9 US patents filed
- ▶ Published (or in press) over 20 papers in high impact journals, including: Chemical Reviews, Adv. Mater., Adv. Energy Mater., Nano-letters, Environ. & Energy Sci., ACS-nano, Electrochem. Comm., J. Power Sources, etc.
- ▶ Technology breakthroughs were reported by NBC News, ScienceDaily, e!Science, Smart Grid News, Smart Grid Today, Energy Daily, Green Car Congress, Materials Today, Ceramics, ...



Acknowledgement

Staff at PNNL:

Business sector manager: Dr. Landis Kannberg

Liyu Li, Soowhan Kim, Gordon Xia, Wei Wang, Greg Coffey, Jianlu Zhang, Birgit Schwenzer, Zimin Nie, Qingtao Luo, Baowei Chen, Fen Chen, Xiaoliang Wei, Dean Matson, Gary Maupin, David Stephenson, Ning Lu, ...

Vince Sprenkle, John Lemmon, Cui Jun, Jin Yong Kim, Xiaochun Lu, Guosheng Li, Kerry Meinhardt, Dave Reed, Brandt Kirby, ...

Daiwon Choi, Xu Wu, Bin Li, ...

Jun Liu, Yuyan Shao, Yuliang Chao, M. Vijayakumar, ...

Michael Kintner-Meyer, Vish Viswanathan, ...